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DOE Packaging Certification Program

**Safety Evaluation Report for
Letter Amendment Request to Ship UF₄ in the ES-3100
Package with a CSI of 2.0**

Docket No. 16-27-9315

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Summary

By letter ^[1] dated June 15, 2016, the National Nuclear Security Administration (NNSA) Office of Material Management and Minimization (NA-23) submitted an application ^[2] to increase the limits for UF₄ currently authorized in Department of Energy (DOE) Certificate of Compliance (CoC) Number 9315, Revision 10, for the Model ES-3100 package, and evaluated in Revision 1 of the ES-3100 Safety Analysis Report for Packaging (SARP).^[3] This change was requested by NNSA for a limited shipping campaign and not as a permanent change to the CoC.

NNSA proposed to increase the package Criticality Safety Index (CSI) from 0.0 to 2.0, based on an increase to the UF₄ loading limit from 3 kg to 24 kg, which corresponds to an increase in ²³⁵U from 2.267 kg to 18.136 kg.

The application documents the results of criticality safety calculations for a modified array to reflect a CSI of 2.0, using the same models, assumptions, and methods evaluated in the SARP for the required array cases with the UF₄ content.

Based on the statements and representations in the application, the criticality safety analyses in the SARP, and Packaging Certification Program (PCP) staff's confirmatory evaluation, and the conditions listed in this Safety Evaluation Report (SER), staff finds that the NNSA request to ship UF₄ in the ES-3100 package with a CSI of 2.0 is acceptable, and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

Evaluation

Chapter 1. General Information Evaluation

1.1 Packaging Description

There are no changes to the packaging design. Detailed packaging descriptions, drawings and contents can be found in the SARP. The components of the packaging include a drum enhanced by impact-limiting and thermal-insulating materials, neutron-absorbing materials, and a containment vessel (CV) inside the drum.

1.2 Contents

The currently authorized limits for UF₄ are listed in Tables 1.3 of the DOE certificate and SARP under the content category of "Uranium Compounds." The applicant proposed to increase the Criticality Safety Index (CSI) from 0.0 to 2.0; to increase the content loading weight from 3 kg to 24 kg, and to increase the corresponding ²³⁵U limit from 2.267 kg to 18.136 kg.

Based on the review of the statements and representations in the application and the SARP, PCP staff concludes that the information provided by the applicant is adequate for evaluation of the package against the requirements of 10 CFR 71, for each technical discipline in the subsequent sections of this SER.

Chapter 2. Structural Evaluation

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no structural issues related to the request to ship UF₄ in the ES-3100 package with a CSI of 2.0.

Chapter 3. Thermal Evaluation

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no thermal issues related to the request to ship UF₄ in the ES-3100 package with a CSI of 2.0.

Chapter 4. Containment Evaluation

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no containment issues related to the request to ship UF₄ in the ES-3100 package with a CSI of 2.0.

Chapter 5. Shielding Evaluation

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no shielding issues related to the request to ship UF₄ in the ES-3100 package with a CSI of 2.0.

Chapter 6. Criticality Evaluation

6.1 Discussion

Highly enriched uranium (HEU) in the form of UF₄ is authorized in DOE Certificate of Compliance (CoC) Number 9315, Revision 10 with limits listed in Section 5(b) in Table 1.3. The ES-3100 SARP only analyzed UF₄ with a CSI of 0.0, based on a loading limit of 3 kg UF₄ that corresponds to a limit of 2.267 kg for ²³⁵U. The applicant proposed to increase the UF₄ limits to a CSI of 2.0, based on a material loading limit of 24 kg UF₄ total mass that corresponds to a limit of 18.136 kg for ²³⁵U. This change is necessary for a limited NNSA shipping campaign.

PCP staff reviewed the criticality safety design of the ES-3100 package described in Chapter 6 of the SARP and the results of additional criticality safety analysis provided in the application. Staff also performed Monte Carlo analyses to independently confirm criticality safety under the most reactive conditions during normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

6.2 Package Description

Packaging

The ES-3100 packaging design includes a stainless steel containment vessel (CV) inside a 30-gallon outer drum (Reference Figures 1.1 and 1.2 of the SARP). The payload is placed in convenience cans or bottles or otherwise protected to prevent contamination of the interior surface of the CV. The packaging design includes two features intended for criticality control: neutron absorber that surrounds the CV and can spacers placed between the convenience cans;

both the neutron absorber and the can spacers are filled with alumina borated cement. The drawings in the SARP provide the dimensions of the relevant packaging components. Chapter 2 of the SARP provides material specifications for the packaging components. Descriptions of the ES-3100 packaging design features include identification of packaging materials, densities and compositions of packaging materials, and the fissile/fissionable material forms, masses, and isotopic compositions of the payloads. The staff confirmed that criticality-related information in the SARP is complete and representative of the actual materials specified for the ES-3100 package.

Contents

The contents of the ES-3100 package include various forms of uranium metal, uranium alloys, uranium oxides, uranyl nitrate hydrate, uranium compounds, and unirradiated TRIGA fuel elements (Reference Tables 1.3, 1.3a, and 1.3b of the SARP for loading limits). The content for the proposed shipment consists of 24 kg of UF₄ (18.136 kg U-235), which is higher than the loading limit of 3 kg of UF₄ with a CSI of 0.0 authorized in the current ES-3100 CoC 9315, Rev. 10.

The application describes the results of criticality safety calculations for the proposed shipment. PCP staff confirmed that the models used in those criticality calculations are consistent with the drawings and the detailed package description given in the SARP.

6.3 Criticality Models

The criticality safety calculations performed by the applicant for the proposed UF₄ shipment were based on detailed KENO V.a models of the ES-3100 package in the SARP. The Standard Composition Library and the 238GROUPEENDF5 nuclear data library in the SCALE code package were used for all KENO V.a calculations in Refs. 2 and 3.

The ENDF 7.0 nuclear data library was used for all the MCNP5 calculations in the PCP staff's confirmatory analyses. Section 6.8 of the SARP and Section 6.9.8.7 of Appendix 6.9.8 of the SARP summarize the determination of the minimum k_{safe} value. The lowest k_{safe} value determined from the validation is 0.924. Therefore, any configurations of ES-3100 packages with $k_{\text{eff}} + 2\sigma < k_{\text{safe}}$ are deemed subcritical. All calculations incorporated sufficient neutron histories to ensure statistical uncertainty (σ) less than 0.002 and adequate convergence. Staff concurs that the benchmark experiments and corresponding bias value are applicable and conservative as applied to the ES-3100 package.

6.4 Summary of Criticality Analysis and Staff's Confirmatory Evaluation

The NCT undamaged package array model for the proposed HEU UF₄ contents consisted of 7×7×3 finite array of packages with a CSI of 2.0. The analyses in Chapter 6 of the SARP show that the maximum reactivity occurs in an array of ES-3100 packages when the CV is flooded and the packaging is dry, referring to a configuration in which: (a) the neutron poison of the body weldment liner inner cavity and the impact absorbing insulation are dry, (b) recesses of the package external to the CV do not contain any residual moisture, and (c) the interstitial space between packages in the array does not contain any residual moisture. The NCT array configurations are based on a fully flooded CV and dry packaging to maximize the k_{eff} of the array.

The CV and single package models were evaluated in Section 6.9.8.5.5 of the SARP and were shown to be below the Upper Subcriticality Limit (USL) for up to 24 kg UF₄. From SARP Section 6.9.8.6 the analyses presented in SARP Sections 6.4, 6.5 and 6.6 demonstrated insignificant difference between the calculated $k_{eff} \pm 2\sigma$ values for undamaged packages in NCT and damaged packages in HAC. Therefore, the HAC array analysis is redundant and was not performed by the applicant.

Table 6-1 of this SER (below) shows the maximum $k_{eff} + 2\sigma$ reactivity results listed in a table from the application and the staff's confirmatory analyses for the proposed UF₄ contents on 7×7×3 array (CSI=2.0), with a fully flooded CV under NCT. Both calculations showed maximum $k_{eff} + 2\sigma$ reactivity values for the most reactive configuration of 13 kg of UF₄ with no interstitial water between the packages.

The maximum $k_{eff} + 2\sigma$ reactivity values are less than the lowest k_{safe} value of 0.924, with a substantial safety margin. Therefore, the ES-3100 package with the proposed UF₄ contents on a 7×7×3 array is subcritical and satisfies the requirements of 10 CFR 71.55(d) and 10 CFR 71.59(a)(1).

Table 6-1. Summary of Y-12 Criticality Analysis and Staff Confirmatory Analysis for the 9315 (ES-3100) Package

UF ₄ Mass (kg)	Y-12 Case	MOIFR	Maximum $k_{eff} + 2\sigma^a$	
			Y-12 (KEVO.V.a)	Staff (MCNP5)
1	1 1	1.0e-20	0.66509	0.66922
5	5 1	1.0e-20	0.84683	0.85447
10	10 1	1.0e-20	0.86702	0.87574
12	12 1	1.0e-20	0.86687	0.87480
13	13 1	1.0e-20	0.86965	0.87550
13	13 4	1.0e-3	0.86720	0.87540
13	13 8	0.3	0.76340	0.79488
14	14 1	1.0e-20	0.86788	0.87491
16	16 1	1.0e-20	0.86523	0.87334
20	20 1	1.0e-20	0.86207	0.86974
24	24 1	1.0e-20	0.85500	0.86467

a) Upper subcritical limit (USL) k_{safe} value is 0.924.

6.5 Criticality Safety Index (CSI) for Nuclear Criticality Control

Based on the NCT/HAC finite array analyses of the proposed UF₄ shipment, with a CSI of 2.0, is acceptable for the ES-3100 package with the proposed UF₄ contents.

6.6 Findings

Based on the statements and representations in the application, the criticality safety analyses in the SARP, and the PCP staff's confirmatory evaluation, staff concluded that the nuclear criticality safety design of the ES-3100 package is acceptable for shipping UF₄ content with a CSI of 2.0, and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

Chapter 7. Package Operations Evaluation

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no package operations issues related to the request to ship UF₄ in the ES-3100 package with a CSI of 2.0.

Chapter 8. Acceptance Test and Maintenance Evaluation

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no acceptance tests and maintenance issues related to the request to ship UF₄ in the ES-3100 package with a CSI of 2.0.

Chapter 9. Quality Assurance Evaluation

Based on the review of the statements and representations in the application and the SARP, and PCP staff's confirmatory evaluation, staff finds that there are no quality assurance issues related to the request to ship UF₄ in the ES-3100 package with a CSI of 2.0.

Conditions of Approval

PCP staff finds the requested change to ship UF₄ in the ES-3100 package with a CSI of 2.0 does not affect the ability of the package to meet 10 CFR Part 71 subject to the following conditions to amend the CoC:

- UF₄ is limited to a CSI of 2.0; the material loading limits are 24 kg of UF₄, of which 18.136 kg is ²³⁵U.
- All other conditions of the certificate remain the same.

Conclusion

Based on the statements and representations in the application, the criticality safety analyses in the SARP, and PCP staff's confirmatory evaluation, and the conditions listed above, staff finds that the NNSA request to ship UF₄ in the ES-3100 package with a CSI of 2.0 is acceptable, and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

References

- [1] *Request for Letter Amendment to Ship UF₄ in the ES-3100 Package with a CSI of 2.0*, CoC USA/9315/B(U)F-96 (DOE), submitted to US Department of Energy Packaging Certification Program, by the National Nuclear Security Administration (NNSA) Office of Material Management and minimization (NA-23), June 15, 2016.
- [2] Alan Wilkinson, *Criticality Evaluation of UF₄ at CSI 2.0 for the ES-3100*, CNS Y-12, LLC Technical Paper, June 15, 2016.
- [3] *Safety Analysis Report for Packaging, Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents*, SP-PKG-801940-A001 Rev. 1, Consolidated Nuclear Security LLC, September 3, 2015.